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COAST AND GEODETIC SURVEY
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The Tsunami of March 9, 1957, as Recorded at Tide Stations

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Technical Bulletin No. 6 presents the factual record of the March 9, 1957, tsunami as shown by the tide gage records and other data on file at the Coast and Geodetic Survey. The record has been examined for various features in order to provide answers to some frequently asked questions about such waves.

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The Tsunami of March 9, 1957, as Recorded at Tide Stations

GARRETT G. SALSMAN, Oceanographer

U.S. Coast and Geodetic Survey

ON MARCH 9, 1957, at $14^h\ 22^m\ 27^s$ Greenwich mean time, a severe submarine earthquake rocked the sea floor some 100 miles southeast of Adak Island in the Aleutian Chain. From an epicenter at 51° N., 175° W. a tsunami was generated which eventually traversed the Pacific to splash the foothills of the Andes Mountains in Chile and cast waves on the shores of distant Pago Pago in Samoa. Over fifty tide stations detected the wave's passage, ranging from small perturbations at La Union, El Salvador to fluctuations exceeding 11 feet at Kahului in the Hawaiian Islands.

A study of 54 tide gage records is presented in this Bulletin. Included are a comparison with previous tsunamis, the part played by the Seismic Sea Wave Warning System in alerting affected areas, a discussion of the wave's various characteristics, numerous tables, and reproductions of a number of the records.

COMPARISON WITH PREVIOUS TSUNAMIS

The three major Pacific tsunamis of the past 13 years are listed in table 1. All originated along the northern rim of the Pacific, one near the Kamchatka Peninsula, the other two south of the Aleutian Chain. The 1952 and 1957 waves were produced by heavier earthquakes than the 1946 tsunami and they were also recorded by more tide gages. Devastation in the Hawaiian Islands, however, was more extensive in the unannounced wave of 1946.

A better criterion of tsunami severity might be wave heights as recorded along different coastlines. Table 2 contains maximum wave heights achieved at 12 different tide stations during the 1946, 1952, and 1957 waves. The maximum waves rose higher at Port Hueneme in 1946 than in 1952 and 1957, at Avila Beach in 1952 than in 1946 and 1957, and at Valparaiso in 1957 than in 1946 and 1952. These varying degrees of wave intensity from place to place are more a function of local topography than distance from epicenter or magnitude of the generating earthquake.

The tsunami of 1946 took 173 lives in the Hawaiian Islands whereas no lives were lost during the later tsunamis. This fact reflects the successful operation of Seismic Sea Wave Warning System established by the Coast and Geodetic Survey following the 1946 catastrophe.

THE SEISMIC SEA WAVE WARNING SYSTEM

It was 1428 Greenwich time on March 9, 1957, when the first phase of the warning system sprang into action at the Honolulu Magnetic Observatory (HMO). The groundwaves of the Aleutian quake had taken only 6 minutes to traverse the ocean floor and trigger the seismograph alarm. Instruments at Fairbanks, Sitka, Berkeley, Tucson, Baguio, Tokyo, and Sapporo also recorded the jolt and forwarded their data to the HMO. Rapid communication was now imperative to ascertain the existence and point of origin of a wave capable of traveling the Pacific at 500 knots or more. Within an hour the epicenter was located at 51° N., 175° W., and tide observers in the path of a possible wave were alerted. Unalaska reported a 4-foot wave at 1547 and Adak had a 9-foot rise 3 minutes later. By 1552, military and civil authorities had received a preliminary warning. Traveltime charts came into play as the wave's theoretical journey across the Pacific was plotted. At 1655, the U. S. Navy, Weather Bureau, and police were furnished estimated arrival times of 1745 at Midway and 1845 at Honolulu.

Table 1.—Major tsunamis, 1946–58

Date	Epicenter near	Magnitude*	Tide gages recording the wave	In Hawaiian Islands: Lives lost	In Hawaiian Islands: Property damage
Apr. 1, 1946	Aleutian Islands	7 1/4	33	173	$25,000,000
Nov. 4 1952	Kamchatka	8 1/4 - 8 1/2	71	0	800,000
Mar. 9, 1957	Aleutian Islands	8 - 8 1/2	54	0	3,000,000

*Modified Mercalli Intensity Scale.

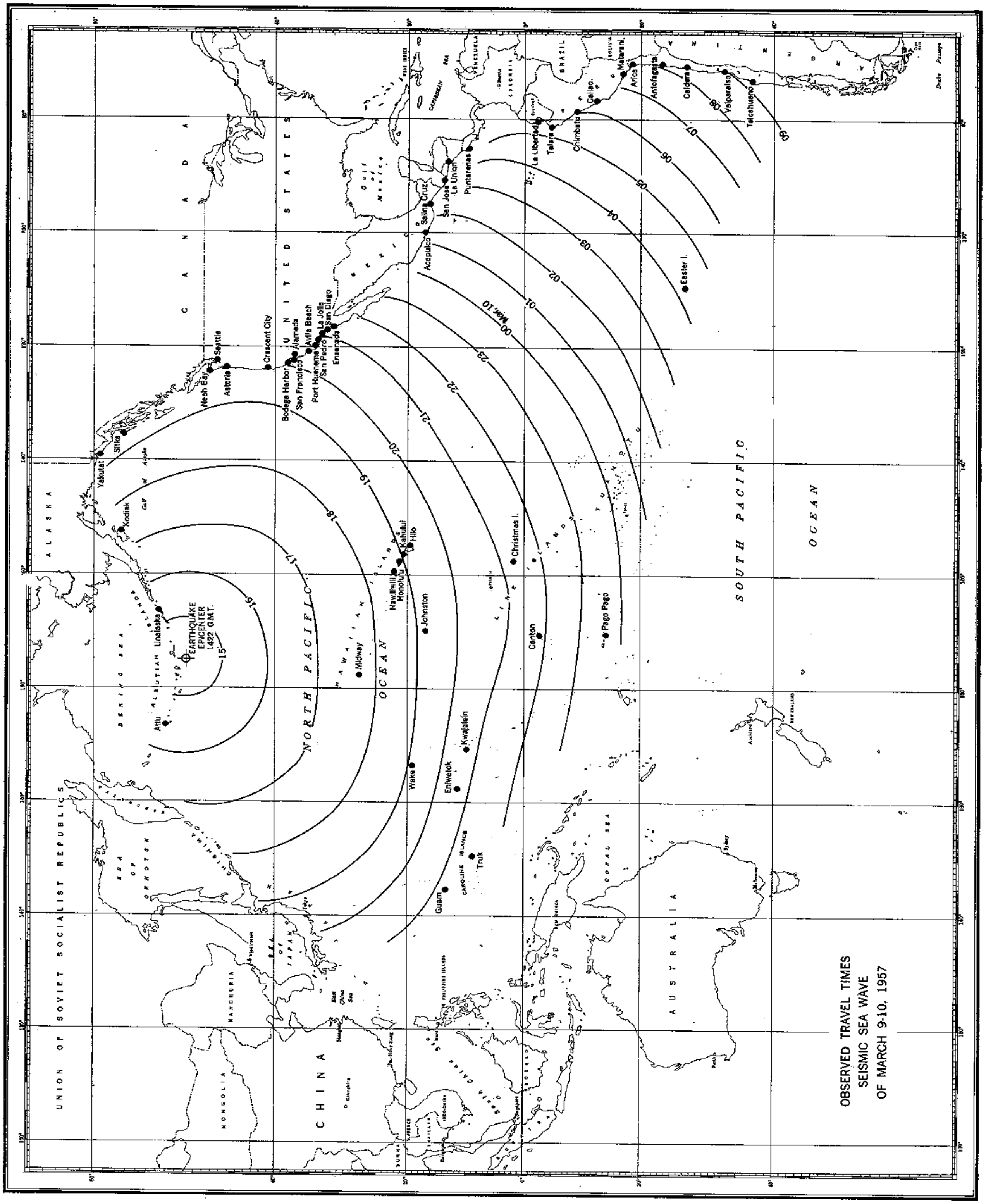
OBSERVED TRAVEL TIMES
SEISMIC SEA WAVE
OF MARCH 9-10, 1957
EARTHQUAKE EPICENTER 1422 G.M.T.
15
16
17
18
19
20
21
22
23
00 Mar. 10
01
02
03
04
05
06
07
08
09
NORTH PACIFIC OCEAN
SOUTH PACIFIC OCEAN
UNITED STATES
CANADA
ALASKA
MEXICO
CHINA
AUSTRALIA
UNION OF SOVIET SOCIALIST REPUBLICS
Attu
Unalaska
Kodiak
Yakutat
Sitka
Neah Bay
Seattle
Astoria
Crescent City
Bodega Harbor
San Francisco
Alameda
Avila Beach
Port Hueneme
San Pedro
La Jolla
San Diego
Ensenada
Acapulco
Salina Cruz
San Jose
La Union
Puntarenas
La Libertad
Talara
Chimbote
Callao
Matarani
Arica
Antofagasta
Caldera
Valparaiso
Talcahuano
Easter I.
Midway
Nawiliwili
Honolulu
Kahului
Hilo
Johnston
Christmas I.
Canton
Pago Pago
Wake
Kwajalein
Eniwetok
Truk
Guam

Table 2.—Maximum recorded rise or fall

(This table lists only places at which gages were operating during all three tsunamis.)

Station	1946	1952	1957
	Feet	*Feet*	*Feet*
Honolulu, T. H.	4.1	4.4	3.2+
Sitka, Alaska	2.6	1.5	2.6
Neah Bay, Wash	1.2	1.5	1.0
Crescent City, Calif	5.9	6.8	4.3
San Francisco, Calif	1.7	3.5	1.7
Avila Beach, Calif	8.5	9.5+	3.5
Port Hueneme, Calif	5.5	4.7	3.5
Los Angeles (Berth 60), Calif	2.5	2.0	2.1
La Jolla, Calif	1.4	0.8	2.0
San Diego, Calif	1.2	2.3	1.5
Antofagasta, Chile	5.9	4.7	3.0
Valparaiso, Chile	5.0+	5.9+	6.7

The 1946 maximum was 8.5 feet at Avila Beach, Calif.
The 1952 maximum was 12.0 feet at Talcahuano, Chile.
The 1957 maximum was 11.2+ feet at Kahului, T. H.

The first wave swept down on Midway at 1733, hit Kaui at 1842, Oahu at 1850, Maui at 1906, and Hawaii at 1911 (see table 6). To the east and west, the wave fronts described graceful arcs reaching to the shores of North America and Japan. By 0920 of the following day they had made their way far into the southern hemisphere to Talcahuano, Chile. Complex refraction and reflection patterns arose near every shore and then set to sea to impose themselves on the primary wave pattern. The Pacific surface shuddered perceptibly for several days before returning to normal.

SPEED AND TRAVELTIME OF WAVES

The speed of any wave in water having a depth of less than half the wavelength is found by the formula

$$S = \sqrt{gd} \qquad (1)$$

where S is the wave speed in feet per second, g is the acceleration due to gravity, and d is the depth of water in feet. Since a tsunami's wavelength is usually in excess of 100 miles, this formula should be applicable, and studies of previous waves, as well as the 1957 data, confirm it. To find S in knots with d given in feet, equation (1) becomes

$$S = 3.36 \sqrt{d} \qquad (2)$$

and to find S in knots with d given in fathoms, it takes the form

$$S = 8.23 \sqrt{d} \qquad (3)$$

Thus it attains speeds greater than 500 knots over oceanic depths, and is slowed considerably in the shoaler waters of bays and harbors as shown by table 3.

Table 3.—Computed wave speeds for various depths

Depth Fathoms	*Speed Knots*	*Depth Fathoms*	*Speed Knots*
10	26	2,000	368
100	82	3,000	451
500	184	4,000	521
1,000	260	5,000	582

The wave will undergo an acceleration or deceleration in passing over ocean bottom of varying depth, and the speed determined by observed traveltime from epicenter to tide station will be an average for the traversed distance. Table 4 shows the observed average speed for the 1957 wave to a number of points. Great circle distances, computed from the latitude and longitude of epicenter and tide station, were used to determine these average velocities. Deviations from this ideal path may have been brought about by refraction near a land mass or travel along a deeper adjacent route. The actual distance traveled by the initial wave in the same interval of time would then be greater, and the actual average speed would be correspondingly larger than indicated in the table.

Table 4.—Observed average wave speed to selected stations

Station	Distance	Travel time	Speed
	Nautical miles	*h. m.*	*Knots*
Eniwetok I.	2,625	6 29	405
Wake I.	2,093	4 45	441
Midway I.	1,371	3 11	431
Christmas I.	3,073	7 17	422
Honolulu, T.H	1,955	4 28	438
Kahului, T.H.	2,005	4 44	424
Hilo, T.H	2,100	4 49	436
Attu, Alaska	450	1 08	397
Unalaska, Alaska	355	1 23	257
Neah Bay, Wash.	1,924	4 58	387
Crescent City, Calif.	2,129	5 11	411
San Francisco, Calif.	2,331	5 56	393
La Jolla, Calif.	2,716	6 36	412
Callao, Peru	6,255	16 14	385
Valparaiso, Chile	7,384	18 26	401

Observed and predicted wave traveltimes to selected stations are listed in table 5. Predictions were made from traveltime charts based on equation (3). The time differences can be attributed to

Table 5.—Wave traveltimes

Station	Observed	Predicted	Observed minus predicted
	h. m.	*h. m.*	*m.*
Midway I................	3 11	3 15	-4
Honolulu, T.H.........	4 28	4 30	-2
Attu, Alaska...........	1 08	1 35	-27
Unalaska, Alaska.....	1 23	2 00	-37
Neah Bay, Wash.......	4 58	5 05	-7
Crescent City, Calif.	5 11	5 10	+1
San Francisco, Calif.	5 56	5 55	+1

any one or a combination of the following factors: (a) tide gage operation, (b) tide record interpretation, (c) unreliable soundings along wave path, (d) improper path, (e) indefinite seismological determination of epicenter, and (f) an epicenter consisting of a large area rather than a point.

It appears that in 1957 the epicenter covered a large area rather than a point. While Central Pacific stations (Midway, Honolulu) received the wave on schedule, stations to the east (Unalaska) and west (Attu) of the epicenter were hit 37 and 27 minutes ahead of time. Imagine a submarine earthquake jolting an hypothetical 350-mile-wide area* in 1,850 fathoms of water. Waves emanating east and west from the *extremities* of this area would proceed in those directions coincident with waves propagated from the *center* of the area 1/2-hour earlier. They would, therefore, arrive at distant points 30 minutes ahead of the time predicted by using a point source epicenter, as was done for the 1957 wave. The greater time differences to the east suggest a displacement of the area's center eastward from the epicenter.

WAVE PERIOD AND LENGTH

Previous tsunamis have shown considerable variation in period as measured by tide gages, and the 1957 wave is no exception. The shortest recorded period of the initial wave was 7 minutes, the longest 55 minutes, and the mean period for all stations listed in table 6 was 17.1 minutes. The mean for island stations was 15.9 minutes and 17.7 minutes for shore stations. Elimination of stations where local oscillations or interference predominate yields a mean of 13.1 minutes which compares favorably with the 14 minutes logged by the long-wave recorder at La Jolla.

Thus, over the deeper regions of the Pacific where the wave had a speed greater than 500 knots, its length was from 100 to 120 nautical miles. This compares to a mean wavelength of 125 nautical miles in 1946 and 170 nautical miles in 1952. The Kamchatka earthquake of 1952, therefore, generated waves of greater length than the two Aleutian quakes.

It can be shown, by differentiation of equation (1) with respect to time, that the acceleration (a) of a seismic sea wave is directly proportional to the tangent of the bottom slope angle (θ). Specifically,

$$a = -\frac{g}{2} \tan \theta \qquad (4)$$

where θ is negative for increasing depth and positive for decreasing. A wave passing over the continental slope is thus *decelerated* by an amount dependent on the slope angle. For a mean slope angle of 2°, this deceleration is approximately 0.6 ft./sec^2., and would cause a wave of oceanic wavelength 150 miles to shrink to a shelf wavelength of only 30 miles.

SOME SPECIAL ASPECTS

Table 6 points out some interesting features of the 1957 tsunami. In it are tabulated the maximum fluctuations attained at different gages and the number of hours that transpired between reception of the initial and maximum waves. At most Pacific Island stations, the highest waves were among the first to hit the beach, while at coastal stations these waves lagged behind the tsunamis' initial appearance by some 6 hours, varying from 3 to 10 hours.

Along the North American coast from Kodiak, Alaska, to Ensenada, Mexico, all 21 tide stations recorded the highest waves during or near the time of high water. Conversely all 7 tide stations on the South American coast from Callao, Peru, to Talcahuano, Chile, recorded the greatest fluctuations near the time of low water. Stations between Ensenada and Callao exhibited no clear relation between highest waves and tide stage, nor did island stations or records from previous tsunamis.

It is also interesting to note that Antofagasta, Chile, was the only tide station recording a drop in water level before a rise. While this is in keeping with the "recession first" theory supported by so many eye witness reports of tsunamis, it contrasts with all the other gage records studied in the 1946, 1952, and 1957 waves.

Neah Bay, at the entrance to the Strait of Juan de Fuca, and Seattle, some 125 miles from the ocean via the strait and Puget Sound, demonstrate the damping effect a wave undergoes in passing from a narrow entrance into a large body of water. The 1-foot waves recorded at Neah Bay in 1946 and 1957 failed to reach the Seattle gage whereas the 1 1/2-foot waves of the 1952 tsunami produced noticeable but small oscillations at Seattle.

*Aftershocks associated with the March 9th earthquake numbered over 200 and took place along a 700-mile stretch of the continental slope.

Table 6.—The Tsunami of March 9, 1957, as recorded on tide gages

(All times are Greenwich)

Waves originated at earthquake epicenter near Adak I. (51° N., 175° W.) at 1422 March 9, 1957

No.	Station	Lat.	Long.	Initial wave: Time of arrival	Initial wave: Travel-time	Initial wave: Period 1st to 2d crest	Highest wave: After initial	Highest wave: Height
		° ′ N	° ′ E	d. h. m.	h. m.	m.	h.	ft.
1.	Apra Harbor, Guam	13 26	144 39	9 21 02	6 40	54	3	0.3
2.	Truk I.	7 22	151 53	9 21 34	7 12	14	3	0.6
3.	Eniwetok I.	11 21	162 21	9 20 51	6 29	9	3	2.0
4.	Kwajalein I.	8 44	167 44	9 20 40	6 18	8a	3	1.8
5.	Wake I	19 17	166 37	9 19 07	4 45	9	6	2.4
		S	W					
6.	Canton I.	2 48	171 43	9 21 54	7 32	12	3	0.8
7.	Pago Pago, Samoa	14 17	170 41	9 23 29	9 07	22	2	1.4
8.	Easter I.	27 09	109 27	10 04 15	13 53	9	6	4.6
		N	W					
9.	Johnston I.	16 45	169 31	9 19 17	4 55	10	2	0.7
10.	Midway I.	28 13	177 22	9 17 33	3 11	12	0	2.7
11.	Christmas I.	1 58	157 28	9 21 39	7 17	12	0	1.1
12.	Honolulu, Oahu, T. H.	21 18	157 52	9 18 50	4 28	14	1	3.2b
13.	Kahalui, Maui, T. H.	20 54	156 28	9 19 06	4 44	22	0	11.2b
14.	Nawiliwili, Kaui, T. H.	21 57	159 21	9 18 42	4 20	11	0	5.6b
15.	Hilo, Hawaii, T. H.	19 44	155 03	9 19 11	4 49	19	0	8.9
16.	Massacre Bay, Attu, Alaska	52 51	186 48	9 15 30	1 08	7a	2	3.8
17.	Unalaska, Alaska	53 54	166 32	9 15 45	1 23	27	2	4.5
18.	Kodiak, Alaska	57 43	152 31	9 16 32c	2 10	--	13	0.6
19.	Yakutat, Alaska	59 33	139 44	9 19 12	4 50	9	8	2.2
20.	Sitka, Alaska	57 03	135 20	9 19 16	4 54	10	7	2.6
21.	Neah Bay, Wash.	48 22	124 37	9 19 20	4 58	13	7	1.0
22.	Astoria, Tongue Pt., Oreg.	46 12	122 46	(d)	- --	--	-	0.5
23.	Crescent City, Calif.	41 45	124 12	9 19 33	5 11	14	6	4.3
24.	Bodega Hbr. Ent., Calif.	38 18	123 03	9 19 42	5 20	30	7	1.9
25.	San Francisco, Calif.	37 48	122 28	9 20 18	5 56	11	5	1.7
26.	Alameda, Calif.	37 47	122 18	9 20 32	6 10	12	5	1.2
27.	Avila Beach, Calif.	35 10	120 44	9 20 08	5 46	18	5	3.5
28.	Port Hueneme, Calif	34 09	119 12	9 20 54	6 32	15	7	3.5
29.	Santa Monica, Calif.	34 00	118 30	9 20 59	6 37	11	15	3.0
	Los Angeles, Calif.							
30.	San Pedro Bkwtr	33 42	118 15	9 21 20	6 58	13	5	1.2
31.	Terminal I.	33 45	118 14	(e)	- --	--	-	0.6
32.	Berth 60	33 43	118 16	9 21 25	7 03	28	5	2.1
33.	Berth 174	33 45	118 16	9 21 18	6 56	55	5	3.1
34.	Long Beach, Calif.	33 45	118 14	9 21 00	6 38	40	5	1.7
35.	Anaheim Bay, Calif.	33 44	118 05	9 21 05	6 43	24	5	2.6
36.	Newport Bay, Calif.	33 36	117 53	9 21 00	6 38	20	6	0.9
37.	La Jolla, Calif.	32 52	117 15	9 20 58	6 36	14	6	2.0
38.	San Diego, Calif.	32 42	117 14	9 21 15	6 53	18	9	1.5
39.	Ensenada, Mexico	31 51	116 38	9 21 10	6 48	13	4	3.4
40.	Acapulco, Mexico	16 51	99 55	10 01 13	10 51	25a	9	2.1
41.	Salina Cruz, Mexico	16 10	95 12	(e)	- --	15a	-	1.2
42.	San Jose, Guatemala	13 55	90 50	(e)	- --	14a	-	0.6
43.	La Union, El Salvador	13 20	87 49	(d)	- --	--	-	0.2
44.	Puntarenas, Costa Rica	9 58	84 50	(d)	- --	--	-	0.8
		S	W					
45.	La Libertad, Ecuador	2 13	80 55	10 06 30	16 08	20	8	3.5
46.	Talara, Peru	4 35	81 17	10 05 25	15 03	12	10	2.6
47.	Chimbatu, Peru	9 05	78 37	(f)	-- --	11a	-	2.6
48.	Callao, Peru	12 03	77 09	10 06 36	16 14	21	6	0.9
49.	Matarani, Peru	17 00	72 07	(f)	-- --	7a	-	4.2

See footnotes at end of table.

Table 6.—The Tsunami of March 9, 1957, as recorded on tide gages—Con.

No.	Station	Lat.	Long.	Initial wave			Highest wave	
				Time of arrival	Travel-time	Period 1st to 2d crest	After initial	Height
		° ' S	° ' W	*d. h. m.*	*h. m.*	*m.*	*h.*	*ft.*
50.	Arica, Chile	18 29	70 20	(e)	-- --	12a	-	3.0
51.	Antofagasta, Chile	23 39	70 25	10 08 04g	17 42	14	6	3.0
52.	Caldera, Chile	27 04	70 50	10 08 14	17 52	16	4	4.2
53.	Valparaiso, Chile	33 02	71 38	10 08 48	18 26	8a	3	6.7
54.	Talcahuano, Chile	36 41	73 06	10 09 20	18 58	24	5	4.6

a. Period of first major oscillation.
b. Exceeded gage limits.
c. Time of initial wave indefinite.
d. Oscillations were noticeable but small.
e. First oscillations hidden by local seiche.
f. First oscillations were small or indefinite.
g. Recorded drop in height first.

The San Francisco Bay situation is similar. Heights decayed from 1.7 to 1.2 feet in proceeding from the Golden Gate to Alameda. In 1952, they dropped from 3.5 to 2.6 feet. A wave height reduction of approximately one third is evident over this 9-mile course. Observed traveltimes to Alameda were 23, 31, and 14 minutes for the 1946, 1952, and 1957 waves, respectively. This shows considerable variance from the computed Alameda traveltime of 20 minutes.

In Los Angeles Harbor the maximum wave was funneled from San Pedro Breakwater to Berth 60 to Berth 174 with a buildup in height from 1.2 to 2.1 to 3.1 feet. It took 5 minutes to traverse the first distance and another 15 minutes to reach Berth 174, at velocities of 15 and 10 knots, respectively. This is considerably less than the calculated speed of 22 and 20 knots. It appears that channel friction and funneling diminish the wave's speed and increase its height.

Another Los Angeles Harbor feature that shows up in table 6 is that the initial wave appears to have reached Berth 174 before it reached Berth 60. This indicates that the first wave was hidden by local interference at Berth 60 and did not register on a gage until it had been funneled up to Berth 174. Later waves of larger amplitude, however, overcame the interference and gave the impression of being the initial waves.

The first waves to reach the Canton Island tide gage had periods of 12 minutes. Succeeding wave periods were gradually reduced to 3 minutes as local effects became eminent. The reduction took approximately 2 hours and was followed by a buildup in height from 0.2 to 0.8 feet.

At La Jolla, Calif., a Scripps Institute wave recorder was operating during this tsunami. Its trace is reproduced along with the tidal marigram for the same day. It can be seen that the instrument has damped out the small period wind waves and long period tide waves evident on the tide record, thus registering only waves of intermediate period. Although their time scales differ appreciably, both curves display corresponding crests, troughs, and amplitudes. The complicated interference pattern indicates the presence of local seiche and storm swell of relatively long periods compounded by the tsunami wave and its local reflections.

RANDOM REPORTS AND OBSERVATIONS

The luxury liner *Lureline*, several freighters, and numerous smaller craft from Hawaiian ports, took to sea upon reception of the wave alert. They rode out the tsunami in deep water without incident.

Meanwhile, at Nawiliwili on Kaui in the Hawaiian Islands, the submarine U.S.S. *Wahoo*, expecting only 1-foot waves, left dockside to ride them out in the harbor. But rapid water level changes of 10 feet or more caused the small funnel-shaped harbor to be alternately drained and refilled. Turbulent currents flooded and ebbed rapidly, buoys were periodically submerged, and the *Wahoo* actually experienced *sternway* at times while leaving the harbor at flank speed (15 knots)!

Capt. E. H. Kirsch of the Coast and Geodetic Survey visited Adak, Alaska, two months after the tsunami and reported: "Earthquake and tidal wave damage have been extensive in this vicinity. Many of the piers have been severely damaged... It is reported that a 26-foot tidal wave occurred at Sand Bay. All of the oil pier outside of the

14-foot curve has been washed away with extreme damage to the oil lines. Many buildings were washed away ..."

Police authorities in Japan reported waves ranging from 6 to 10 feet high struck the eastern shore of Hokkaido, northernmost Japanese island. At least 32 houses were flooded, 18 boats damaged, and roads and embankments destroyed in the Hakodate area. Farther east, in the Kushiro area, 9 houses were destroyed and another 19 damaged. Along the eastern shore of northern Honshu, 83 houses were damaged and 19 boats were washed away. There was no loss of life.

From the Marquesas Islands, the U. S. Fish and Wildlife Ship *Gilbert* radioed: "Tidal wave first noticed at 1356 local time, reached peak at 1610 with a range of 20 feet."

The Associated Press reported a surprise sweep of water raced into San Diego Bay 5 hours after the alert had ended. It smashed a boat slip on Shelter Island, snapped the mooring of the former Navy submarine chaser *Halcyon*, and damaged seven small craft.

Mr. Joe Arakaki, correspondent of the *Honolulu Star-Bulletin*, reported the north shore of Kauai was hard hit by waves that reached a peak of 10 feet. At Wainika, 4 houses were washed out to sea, and at Kalihiwai several homes were completely destroyed. On the south shore, 4 sampans were either capsized or left stranded on the breakwater by 9-foot waves. Bridges were knocked out and highways flooded as the damage toll more than doubled that incurred on Kaui during the unannounced 1946 wave.

On Oahu, the water rose 5 feet along the north shore to flood at least 50 homes, to move 30 dwellings off their foundations, to wash over the highway at Halweiwa, and to cause considerable damage to bridges and buildings.

Kahului harbor on Maui was left empty when the water receded. The Coast Survey tide gage recorded 5 waves with heights in excess of 9 feet during the first 90 minutes of the tsunami, two being greater than 11 feet.

At Lanikai on the western shore of Hawaii, Mrs. Anne Powlison watched both the 1946 and 1957 waves from her hilltop house. "In 1946," she said, "Kailua Bay drained only once. This time the water receded several times, but the bay never drained completely."

The *Honolulu Sunday Advertiser* reported waves were 40 feet high near Scotch Cap on Unimak in the Aleutian Islands. It was here in 1946 that waves destroyed Scotch Cap Light, 57 feet above mean sea level. Waves from the latter had less distance to travel and approached from an obstruction-free direction.

TIDE GAGE RECORDS

Ten of the fifty-four tide gage records examined are reproduced in this Bulletin. The Attu and Unalaska records show the tsunamis' effect in the North Pacific, while records for Eniwetok, Midway, Kahului, and Pago Pago are representative of the Central Pacific. The Crescent City and La Jolla records are typical of the North American coast, while Talara and Antofagasta show the wave's nature on South American shores.

These segments of the gage records are accompanied by time and height scales to aid in estimating periods and amplitudes. Times are Greenwich; heights are in feet and refer to no specific datum. Although the tsunamis' effect continued for several days, these record portions contain the major oscillations at each station and exponential damping can be assumed to have occurred thereafter.

The standard tide gage of the Coast and Geodetic Survey is primarily designed to record long period tide waves, and its use to record and study a tsunami has inherent disadvantages. Due to the small intake to the tide gage float well, short period wave heights are dampened and there is a slight time lag between reception of and response to the waves. In addition, time intervals of less than 2 minutes are difficult to obtain because of the gage's small time scale. These facts should be kept in mind when studying the records.

CONCLUSION

This tsunami was the largest to course the Pacific since 1952. It had a period of 13.1 minutes, a wavelength of nearly 120 miles, and its speed conformed admirably with the long wave velocity equation. Wave heights at different places varied considerably showing a greater dependence on local topography than on quake distance and intensity. At one location, currents in excess of 15 knots were observed.

While substantial lags in arrival time indicate interference at several stations, premature arrivals at two stations suggest the waves were propagated from an extensive epicentral area rather than a point source. All the tide stations (except one) recorded an initial rise in water level followed by a fall.

The Seismic Sea Wave Warning System issued timely alerts to endangered islands and low lying coastal areas. Property damage was thus minimized and there was no loss of life due to the wave. This was the system's second "call to arms," and its second success.

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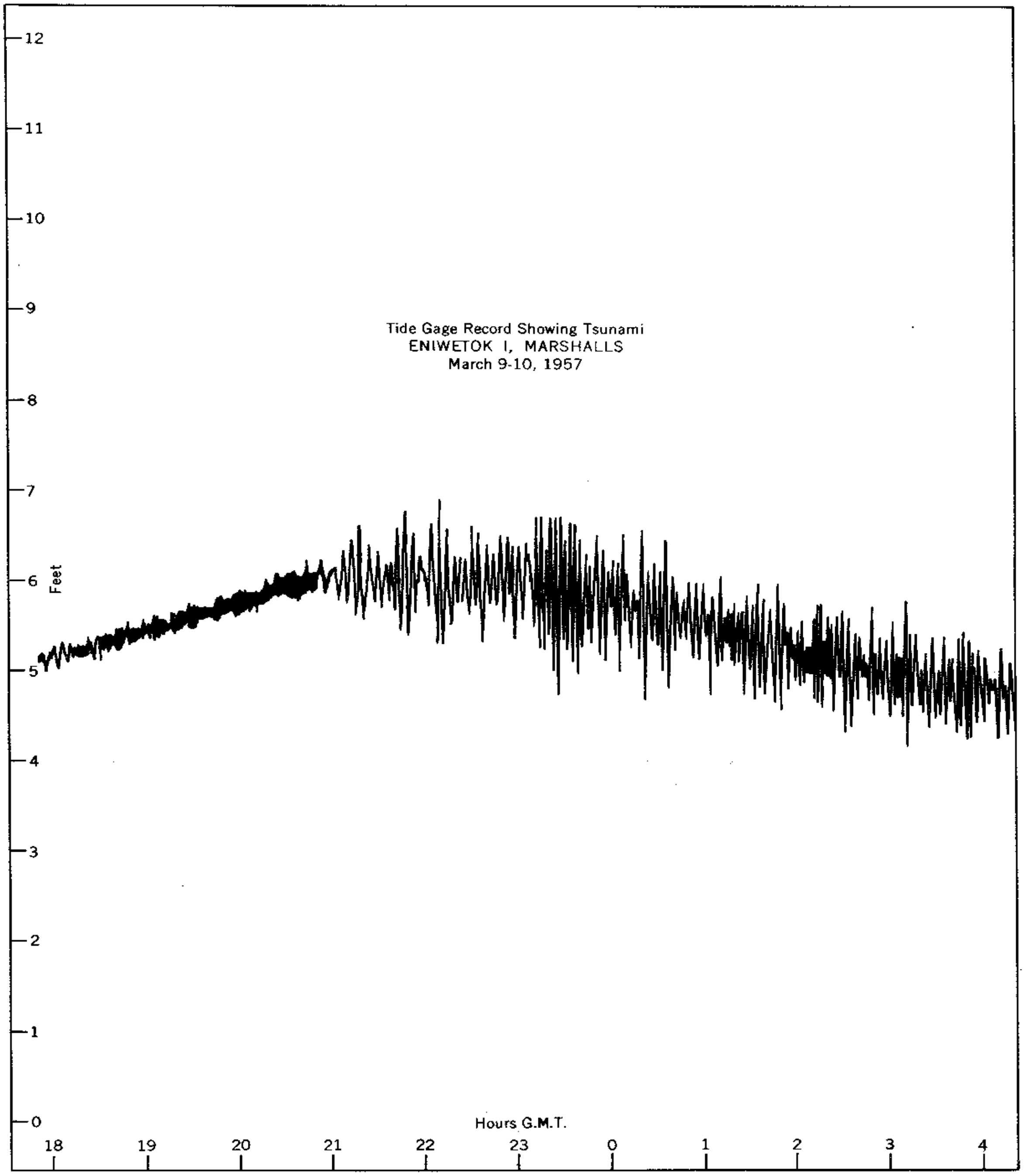
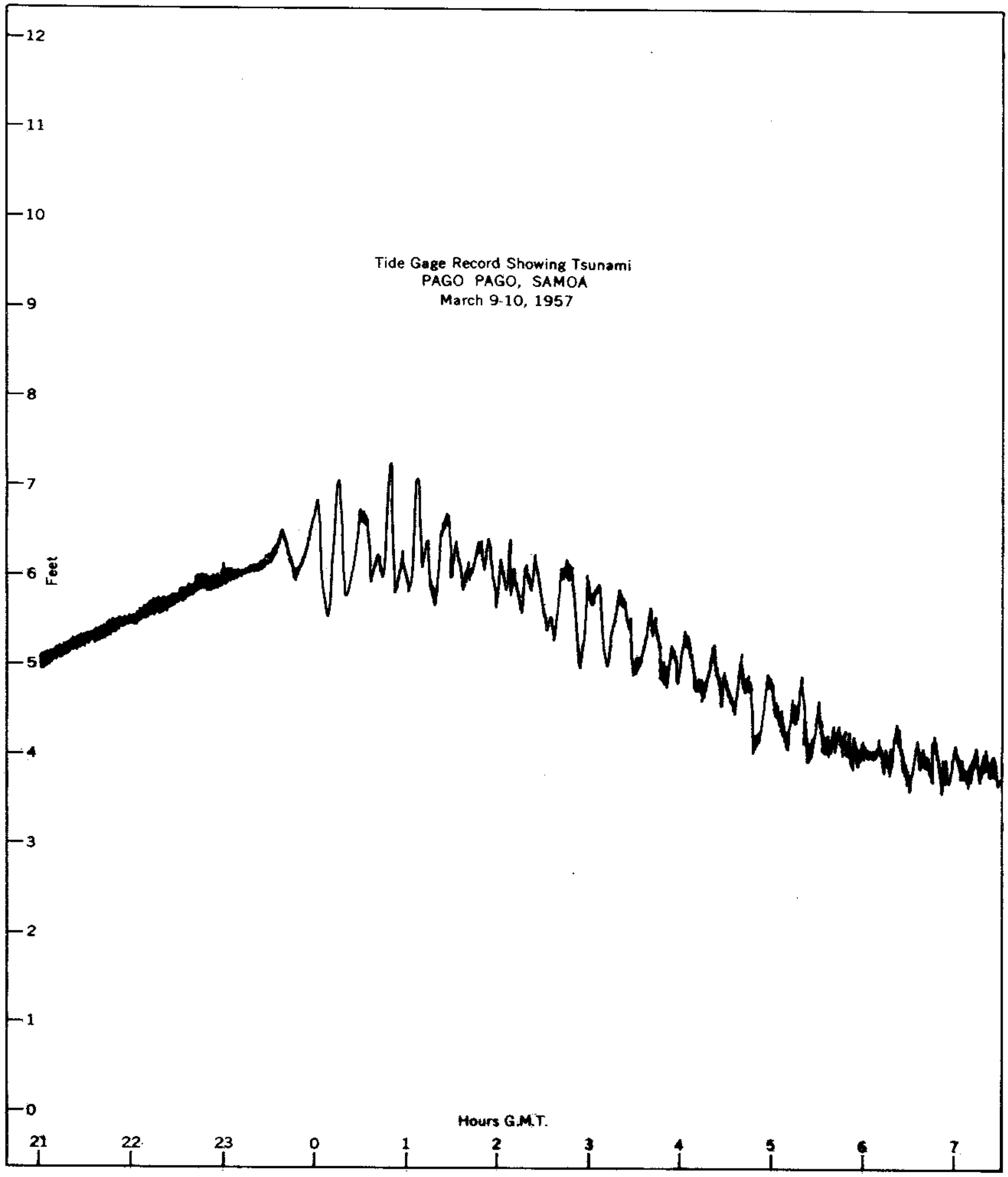
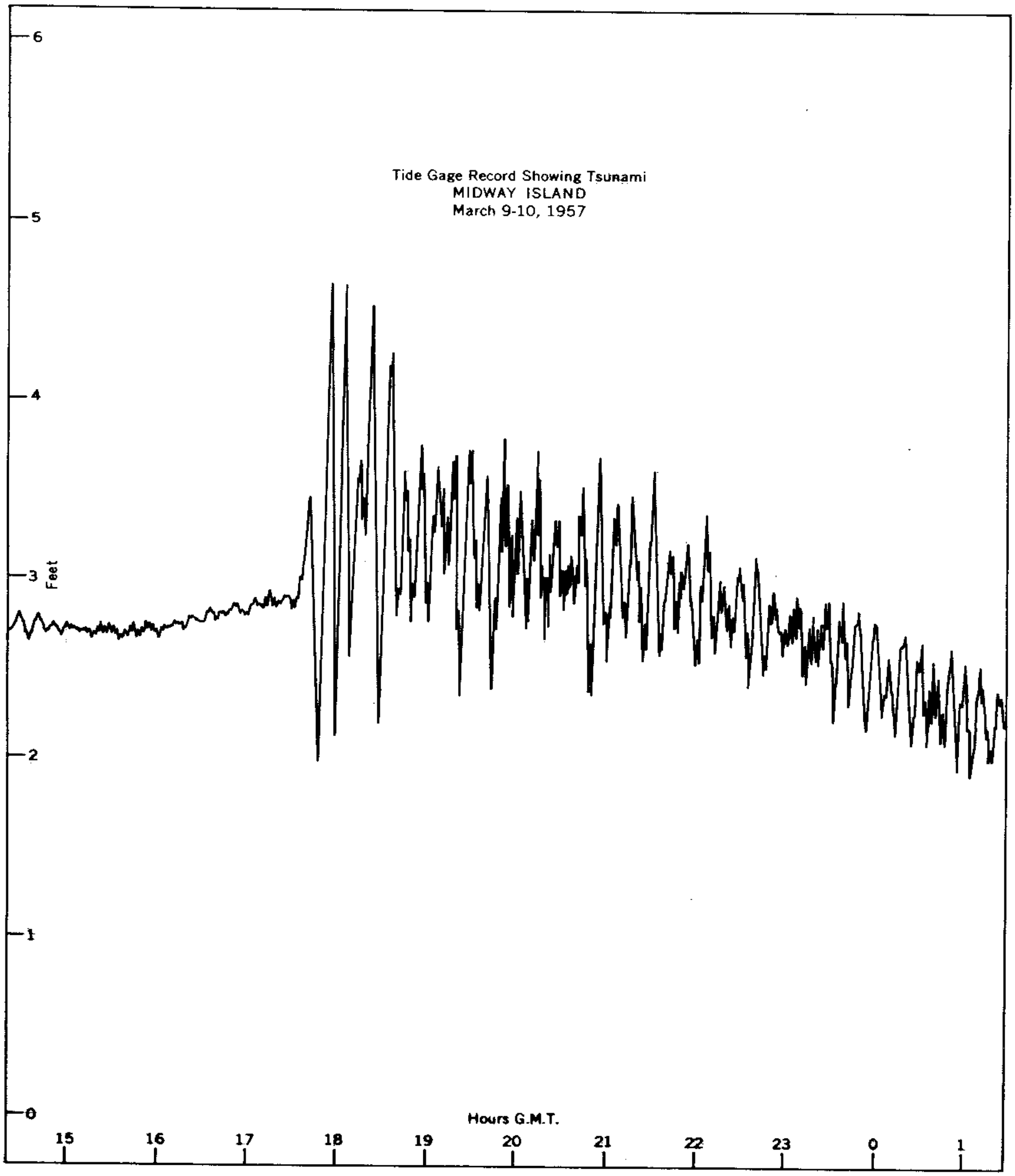
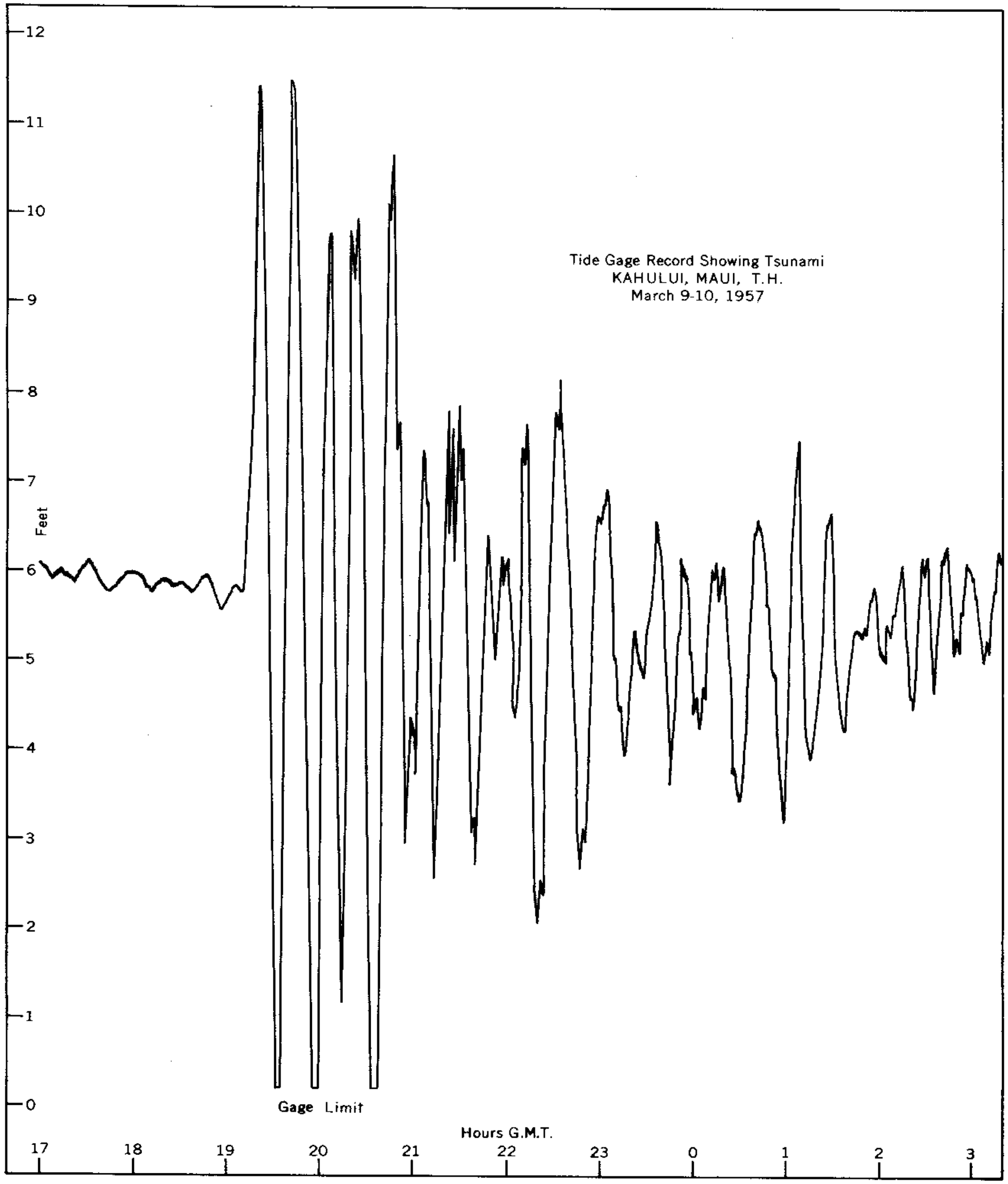
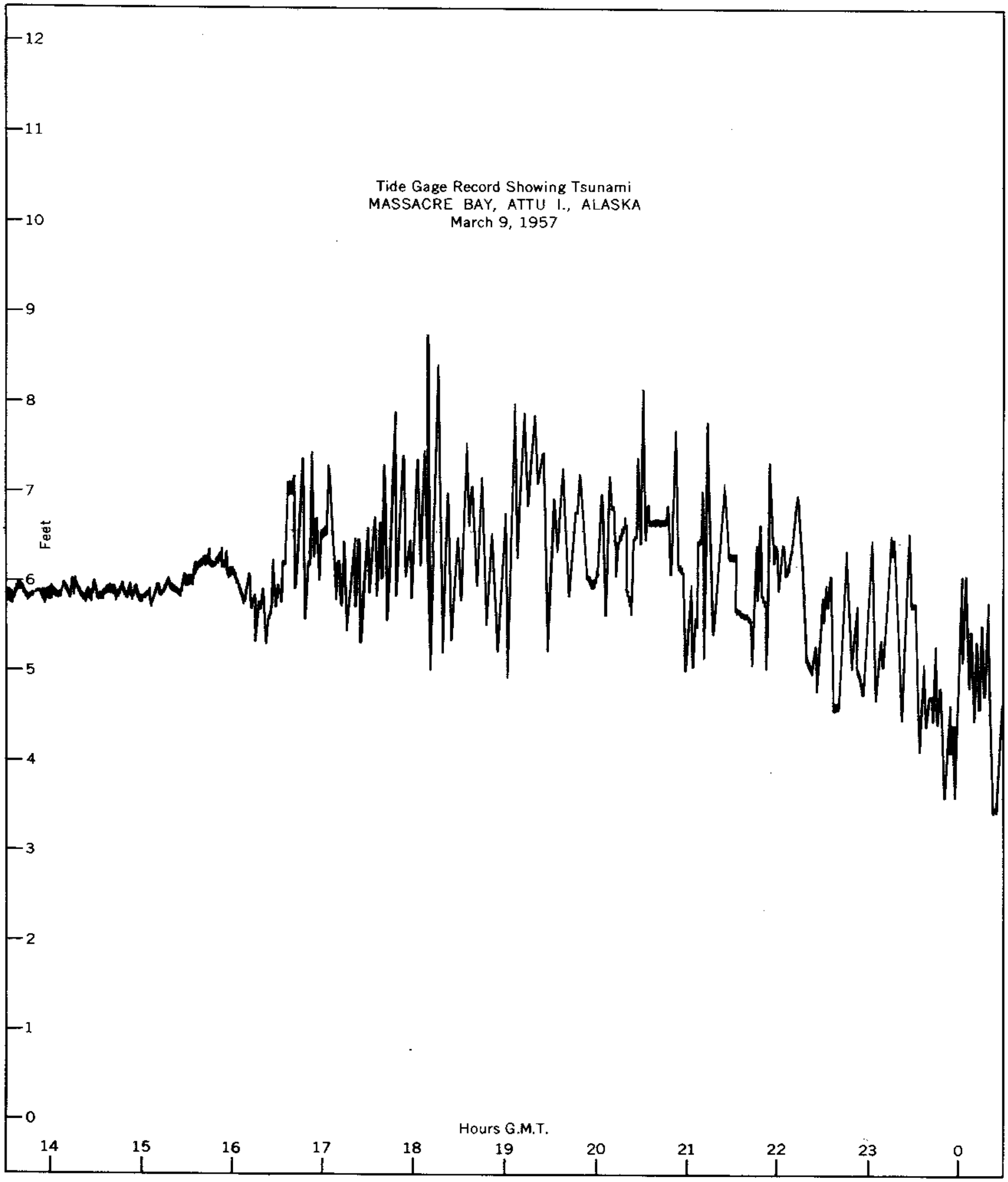
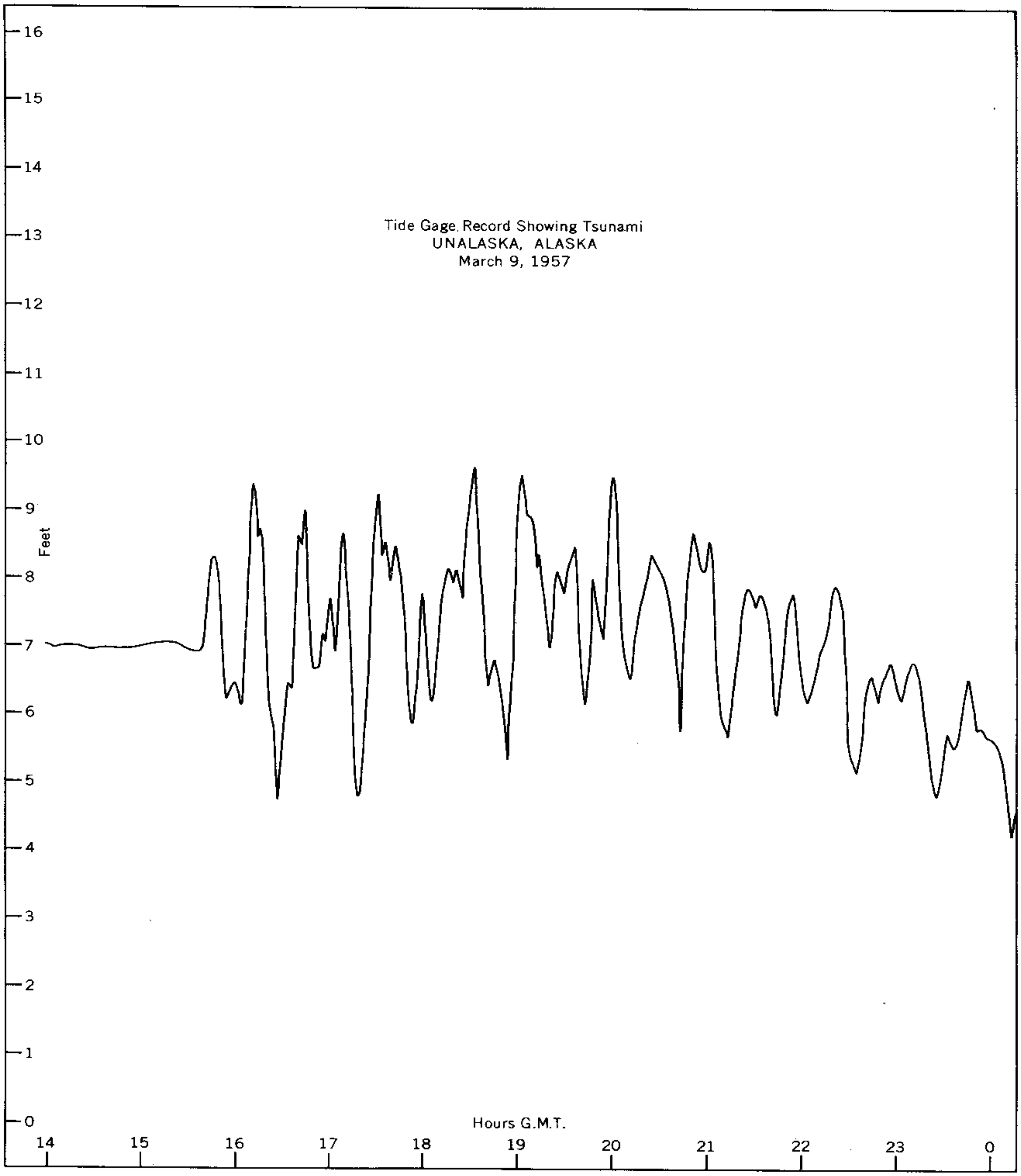



Tide Gage Record Showing Tsunami
PAGO PAGO, SAMOA
March 9-10, 1957
Feet
12
11
10
9
8
7
6
5
4
3
2
1
0
Hours G.M.T.
21
22
23
0
1
2
3
4
5
6
7

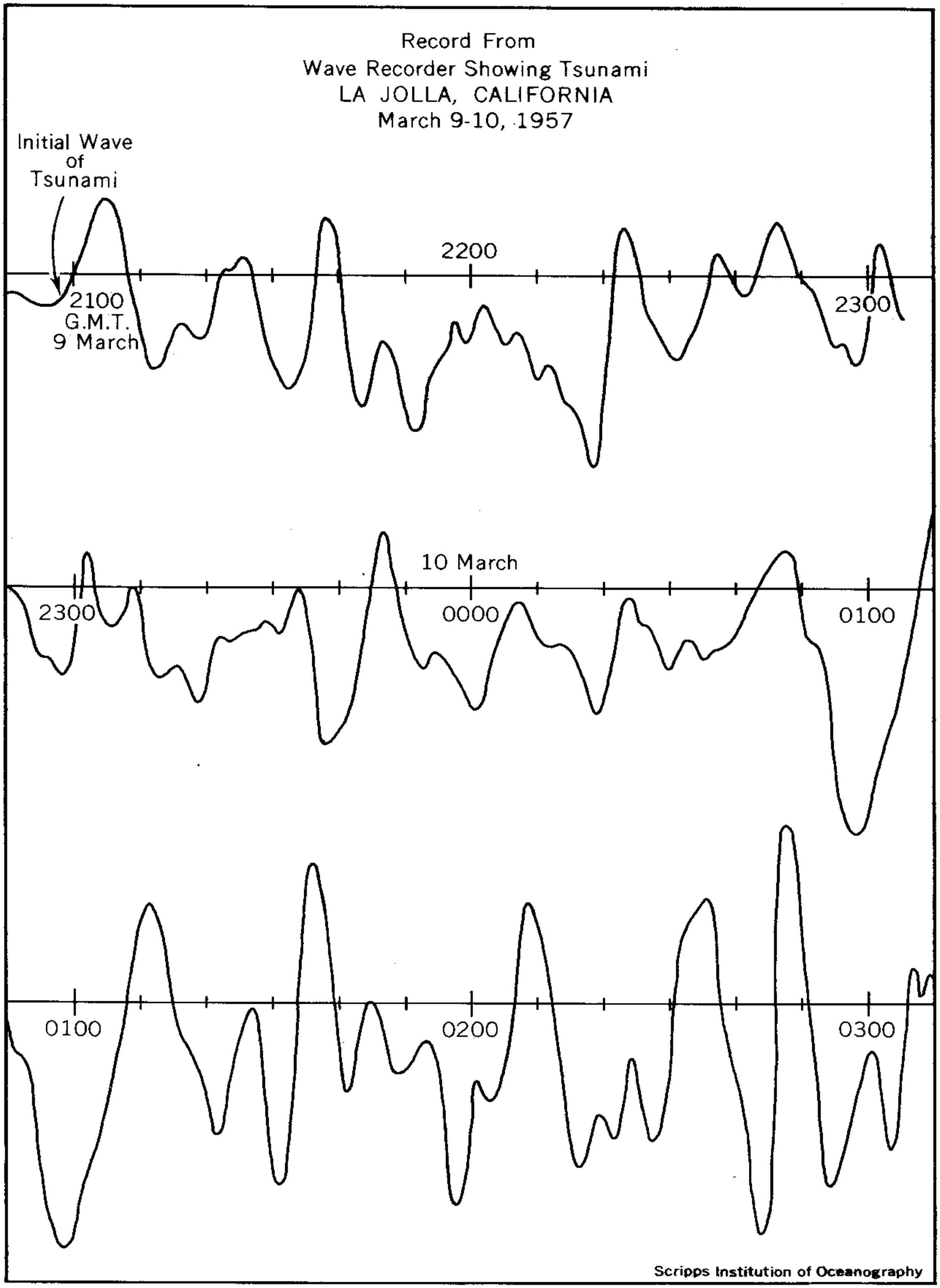

Tide Gage Record Showing Tsunami
MIDWAY ISLAND
March 9-10, 1957
Feet
6
5
4
3
2
1
0
Hours G.M.T.
15
16
17
18
19
20
21
22
23
0
1

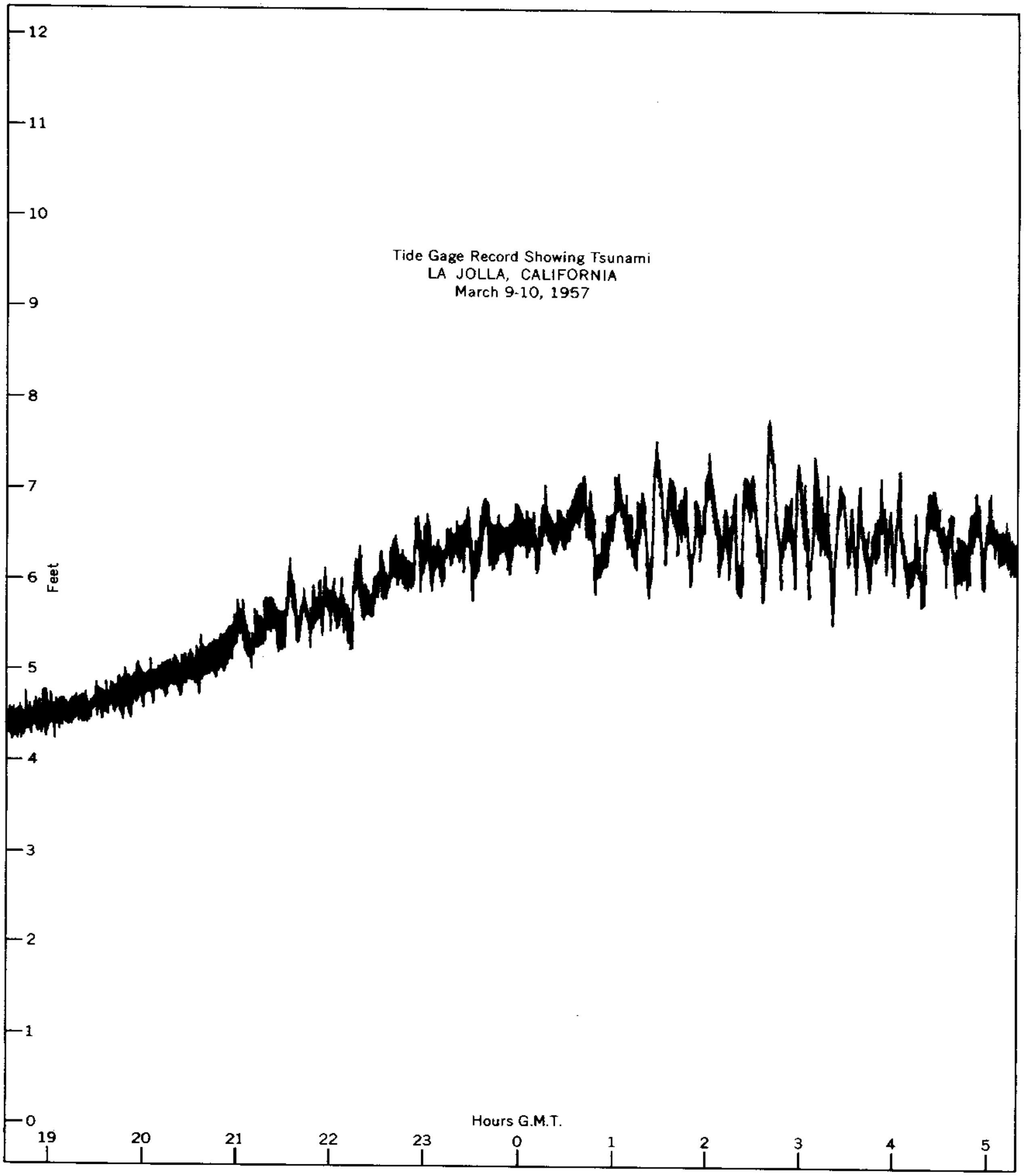

Tide Gage Record Showing Tsunami
KAHULUI, MAUI, T.H.
March 9-10, 1957
Feet
12
11
10
9
8
7
6
5
4
3
2
1
0
Gage Limit
Hours G.M.T.
17
18
19
20
21
22
23
0
1
2
3

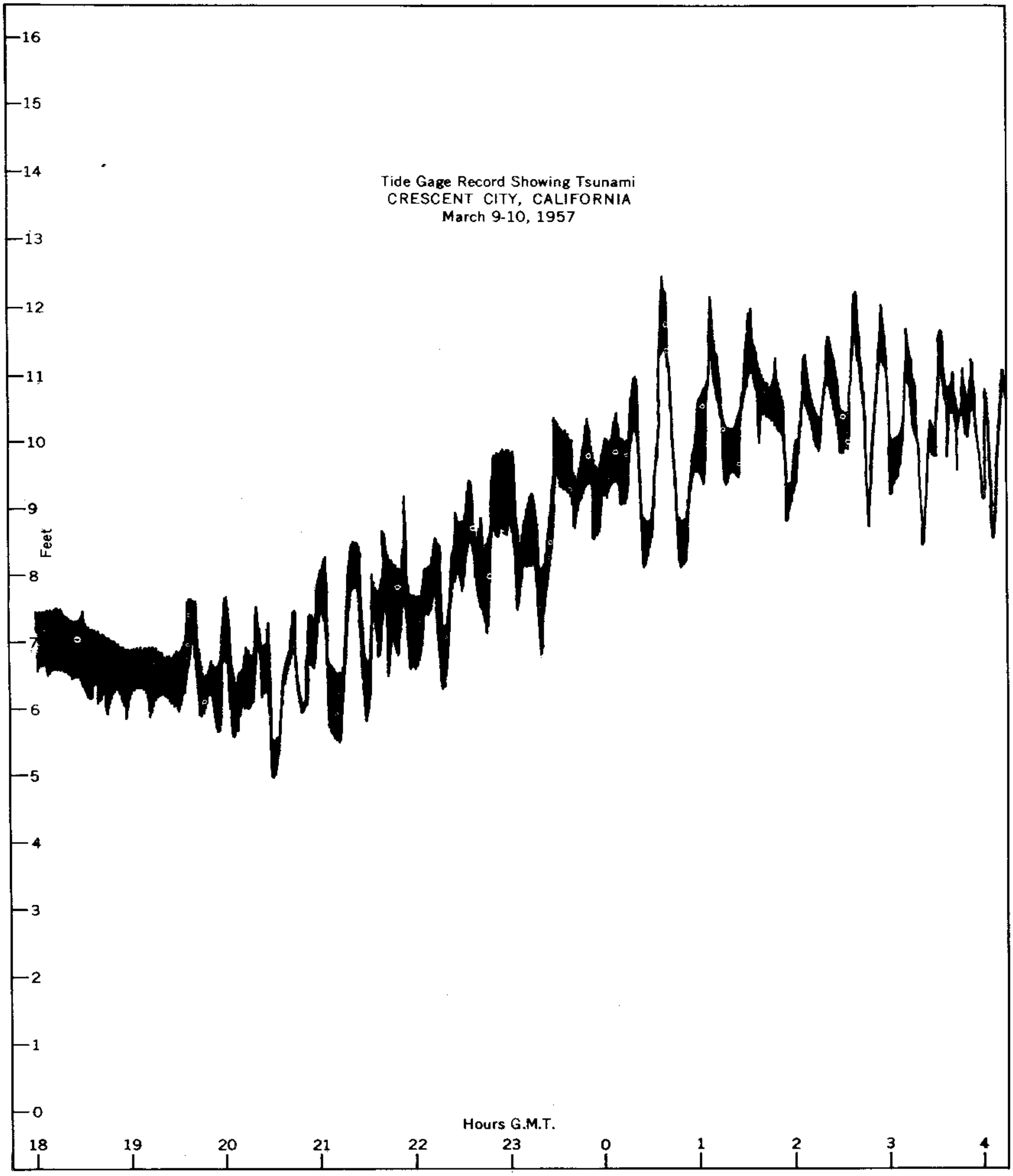

Tide Gage Record Showing Tsunami
MASSACRE BAY, ATTU I., ALASKA
March 9, 1957
Feet
12
11
10
9
8
7
6
5
4
3
2
1
0
Hours G.M.T.
14
15
16
17
18
19
20
21
22
23
0

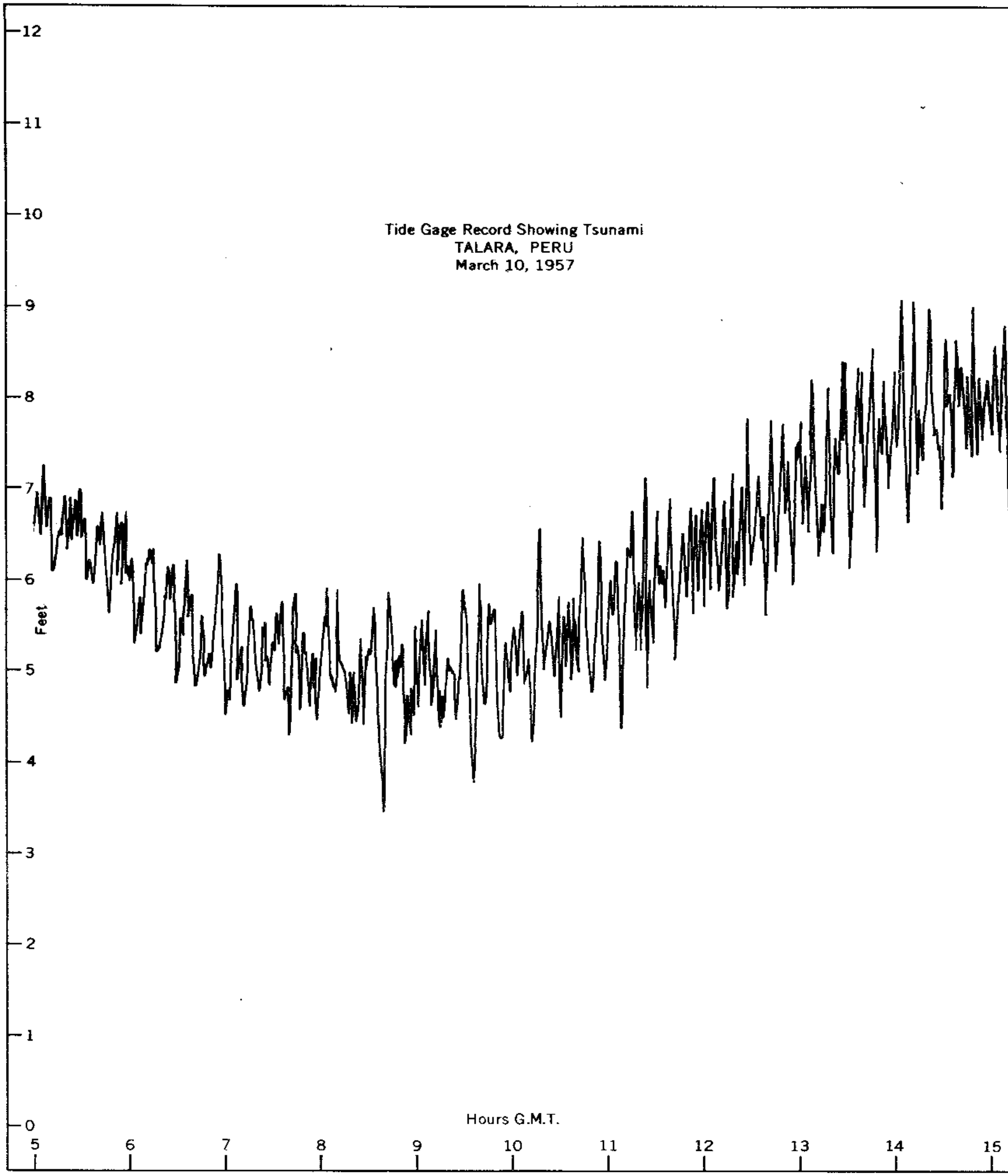


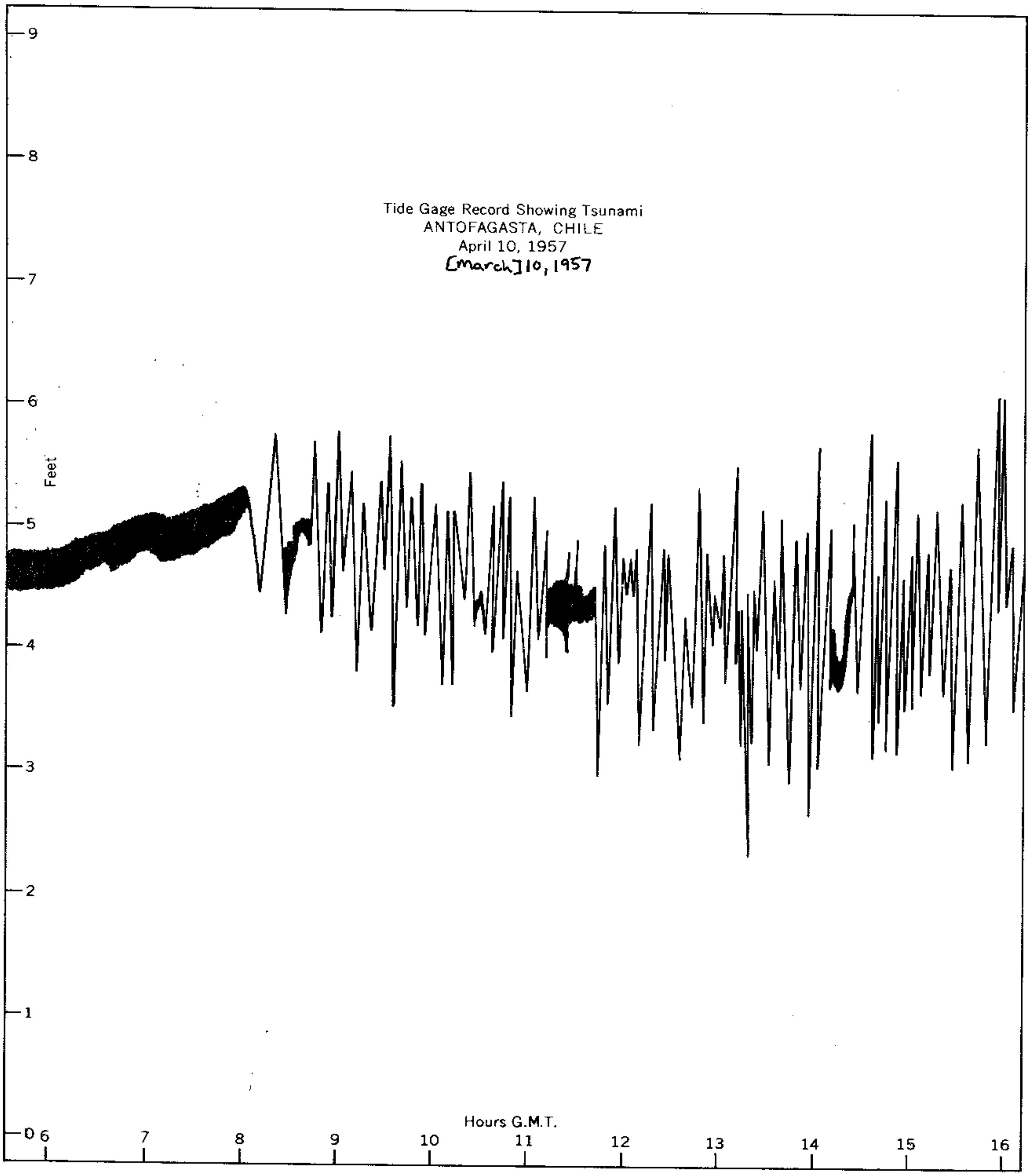
Tide Gage Record Showing Tsunami
UNALASKA, ALASKA
March 9, 1957
Feet
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Hours G.M.T.
14
15
16
17
18
19
20
21
22
23
0


Record From
Wave Recorder Showing Tsunami
LA JOLLA, CALIFORNIA
March 9-10, 1957
Initial Wave
of
Tsunami
2200
2100
G.M.T.
9 March
2300
10 March
2300
0000
0100
0100
0200
0300
Scripps Institution of Oceanography


Tide Gage Record Showing Tsunami
LA JOLLA, CALIFORNIA
March 9-10, 1957
Feet
12
11
10
9
8
7
6
5
4
3
2
1
0
Hours G.M.T.
19
20
21
22
23
0
1
2
3
4
5


Tide Gage Record Showing Tsunami
CRESCENT CITY, CALIFORNIA
March 9-10, 1957
Feet
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Hours G.M.T.
18
19
20
21
22
23
0
1
2
3
4


Tide Gage Record Showing Tsunami
TALARA, PERU
March 10, 1957
Feet
Hours G.M.T.
0
1
2
3
4
5
6
7
8
9
10
11
12
5
6
7
8
9
10
11
12
13
14
15


Tide Gage Record Showing Tsunami
ANTOFAGASTA, CHILE
April 10, 1957
[March] 10, 1957
Feet
9
8
7
6
5
4
3
2
1
0
Hours G.M.T.
6
7
8
9
10
11
12
13
14
15
16